

AMENDMENTS TO THE CLAIMS:

This listing of claims will replace all prior versions and listings of claims in the application:

1. (Currently amended) A pattern measuring apparatus comprising:

a storage device to store a plurality of images of a pattern to be measured and predetermined edge reference data, the predetermined edge reference data comprising a plurality of pixels that have an intensity gradient, ~~the images having been captured by an external imaging device at different focal distances;~~

an external imaging device to capture the images at different focal distances;

a processor to, for each of the images, (i) scan the image, using the predetermined edge reference data, to detect edge points of the image and (ii) compare the predetermined edge reference data to the intensity values of the image at the edge points to generate ~~output~~ a plurality of correlation values, each of the correlation values indicating that indicate correlations a correlation between the edge reference data and the intensity value of the physical image at a respective edge point ~~points~~;

a calculator to, for each of the images, calculate a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing that expresses a correlation between the predetermined edge reference data and the detected edge points of the image, ~~based on the correlation values wherein each of the standardized correlation values corresponds to one of the images;~~

a determinator to, for each of the images, determine an in-focus state of the image, based on the standardized correlation value for the image;

an image selector to select one of the images from the plurality of images, the determined in-focus state of the selected image matching a preselected in-focus state; and

a measurer to process the selected image to measure the pattern.

2. (Previously Presented) The pattern measuring apparatus according to claim 1, wherein the external imaging device includes an optical system that is capable of adjusting a focal position thereof within a range defined by an integer multiple of a predetermined step width from a predetermined initial value, and

the plurality of images have been captured at each of a plurality of focal positions calculated by adding integer multiples of the step width to the initial value.

3. (Previously Presented) The pattern measuring apparatus according to claim 1, wherein the image selector selects a plurality of the images, the determined in-focus states of the selected images matching preselected in-focus states,

the pattern measuring apparatus further comprises an image processor to perform alignment processing among the selected images and superimpose in a single coordinate system the edge points of the selected images, and

the measurer measures the pattern on the basis of position coordinates of the edge points that have been superimposed in the single coordinate system.

4. (Previously Presented) The pattern measuring apparatus according to claim 1, wherein the image selector selects a plurality of the images, the determined in-focus states of the selected images matching preselected in-focus states,

the pattern measuring apparatus further comprises an image processor to perform alignment processing among the selected images and perform image processing to combine the selected images, and

the measurer measures the pattern on the basis of the combined images.

5. (Previously Presented) The pattern measuring apparatus according to claim 1, wherein only edge points that have been detected in previously scanned images and that are within a predetermined range are scanned with the predetermined edge reference data.

6. (Previously Presented) The pattern measuring apparatus according to claim 1, wherein the pattern has a plurality of edges,

the calculator classifies the detected edge points into an edge point group for each of the edges, and calculates the standardized correlation value for each of the edge point groups that have been classified, and

the determinator determines the in-focus state of the image for each of the edge point groups that have been classified.

7. (Currently amended) ~~A pattern measuring apparatus that is connectable to an external imaging device and that measures a pattern on the basis of an image of the~~

~~pattern that is supplied from the external imaging device, the external imaging device capturing the image of the pattern with an optical system, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value, the pattern measuring apparatus comprising:~~

a storage device to store predetermined edge reference data comprising a plurality of pixels that have an intensity gradient;

an external imaging device to capture images of a pattern with an optical system, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

a processor to, for each of the images, (i) scan the image, using the predetermined edge reference data, to detect edge points of the image and (ii) compare the predetermined edge reference data to the intensity values of the image at the edge points to generate output a plurality of correlation values, each of the correlation values indicating that indicate correlations a correlation between the predetermined edge reference data and the intensity value of the image at a respective edge point points;

a calculator to, for each of the images, calculate a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing that expresses a correlation between the predetermined edge reference data and the detected edge points of the image, based on the correlation values wherein each of the standardized correlation values corresponds to one of the images;

a determinator to, for each of the images, determine an in-focus state of the image, based on the standardized correlation value for the image;

a measurer to, for each of the images, process the image to measure the pattern, if the determinator has determined that the in-focus state of the image matches a preselected in-focus state; and

a focal-position controller to, for each of the images, generate and output control signals to change the focal position of the optical system of the external imaging device, if the determinator has determined that the in-focus state of the image does not match the preselected in-focus state.

8. (Previously Presented) The pattern measuring apparatus according to claim 7, wherein only a predetermined range of edge points that have been detected in previously scanned images are scanned with the predetermined edge reference data.

9. (Previously Presented) The pattern measuring apparatus according to claim 7, wherein the pattern to be measured has a plurality of edges,

the calculator classifies the detected edge points into an edge point group for each of the edges to calculate the standardized correlation value for each of the edge point groups that have been classified, and

the determinator determines the in-focus state of the image for each of the edge point groups that have been classified.

10. (Previously Presented) The pattern measuring apparatus according to claim 7, wherein the standardized correlation value is calculated by using a plurality of sets of predetermined edge reference data.

11. (Currently amended) A method of measuring a pattern ~~based on a plurality of images of the pattern captured by an imaging device at different focal positions, the method~~ comprising:

capturing a plurality of images of a pattern at different focal distances with an imaging device;

detecting edge points of each of the images by scanning the image using predetermined edge reference data that comprises a plurality of pixels having an intensity gradient;

comparing, for each of the images, the predetermined edge reference data to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the edge reference data and the intensity value of the image at a respective edge point;

calculating, for each of the images, a standardized correlation value based on the correlation values of the image, the standardization correlation value expression that expresses a correlation between the predetermined edge reference data and the detected edge points of the image, wherein each of the standardized correlation values corresponds to one of the images;

determining, for each of the images, an in-focus state of the image, based on the standardized correlation value for the image;

selecting one of the images from the plurality of images, the determined in-focus state of the selected image matching a preselected in-focus state; and

processing the selected image to measure the pattern.

12. (Previously Presented) The pattern measuring method according to claim 11, wherein the imaging device includes an optical system that is capable of adjusting a focal position thereof within a range defined by an integer multiple of a predetermined step width from a predetermined initial value, and

the plurality of images have been captured at each of a plurality of focal positions calculated by adding integer multiples of the step width to the initial value.

13. (Previously Presented) The pattern measuring method according to claim 11, wherein a plurality of the images are selected, the determined in-focus states of the selected images matching preselected in-focus states,

the pattern measuring method further comprises aligning the selected images and superimposing the edge points of the selected images in a single coordinate system, and

the pattern is measured on the basis of position coordinates of the superimposed edge points.

14. (Previously Presented) The pattern measuring method according to claim 11, wherein a plurality of the images are selected, the determined in-focus states of the selected images matching preselected in-focus states,

the pattern measuring method further comprises aligning the selected images and combining the selected images, and

the pattern is measured based on the combined images.

15. (Previously Presented) The pattern measuring method according to claim 11, further comprising:

scanning, using the predetermined edge reference data, only a predetermined range of edge points that have been detected in previously scanned images.

16. (Previously Presented) The pattern measuring method according to claim 11, wherein the pattern to be measured has a plurality of edges,

the pattern measuring method further comprises classifying the detected edge points into an edge point group for each of the edges,

the standardized correlation value is calculated for each of the edge point groups that have been classified, and

the in-focus state of the image is determined for each of the edge point groups that have been classified.

17. (Previously Presented) The pattern measuring method according to claim 11, wherein the standardized correlation value is calculated by using a plurality of sets of predetermined edge reference data.

18. (Currently amended) A method of measuring a pattern ~~based on an image of the pattern that is captured by an imaging device, the imaging device including an optical system with a focal position thereof being adjustable with respect to the pattern~~

~~by an integer multiple of a predetermined step width from an initial value, the method~~
comprising:

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of the image by scanning the image using predetermined edge reference data that comprises a plurality of pixels having an intensity gradient;

comparing the predetermined edge reference data to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the edge reference data and the intensity value of the image at a respective edge point;

calculating a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing ~~that expresses~~ a correlation between the predetermined edge reference data and the detected edge points of the image;

determining an in-focus state of the image, based on the standardized correlation value;

processing the image to measure the pattern, if it has been determined that the in-focus state matches a preselected in-focus state; and

capturing a new image of the pattern at a different focal position, if it is determined that the in-focus state does not match the preselected in-focus state.

19. (Currently amended) A method of manufacturing a semiconductor device comprising a method of measuring a pattern ~~based on a plurality of images of the pattern that are captured different focal positions by an imaging device, the method comprising~~ including:

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of each of the images by scanning the image using predetermined edge reference data that comprises a plurality of pixels having an intensity gradient;

comparing, for each of the images, the predetermined edge reference data to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the edge reference data and the intensity value of the image at a respective edge point;

calculating, for each of the images, a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing that
expresses a correlation between the predetermined edge reference data and the detected edge points of the image, wherein each of the standardized correlation values corresponds to one of the images;

determining, for each of the images, an in-focus state of the image, based on the standardized correlation value for the image;

selecting one of the images from the plurality of images, the determined in-focus state of the selected image matching a preselected in-focus state; and
processing the selected image to measure the pattern.

20. (Currently amended) A method of manufacturing a semiconductor device comprising a method of measuring a pattern ~~based on an image of the pattern that is captured by an imaging device, the imaging device including an optical system with a focal position thereof being adjustable with respect to the pattern by an integer multiple of a predetermined step width from an initial value, the method comprising~~ including:

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of the image by scanning the image using predetermined edge reference data that comprises a plurality of pixels having an intensity gradient;

comparing the predetermined edge reference data to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the edge reference data and the intensity value of the image at a respective edge point;

calculating a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing ~~that expresses~~ a correlation between the predetermined edge reference data and the detected edge points of the image;

determining an in-focus state of the image, based on the standardized correlation value;

processing the image to measure the pattern, if it has been determined that the in-focus state matches a preselected in-focus state; and

capturing a new image at a different focal position, if it is determined that the in-focus state does not match the preselected in-focus state.

21. (New) A pattern measuring apparatus comprising:

an edge model producing unit to produce a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

a storage device to store a plurality of images of a pattern to be measure and the pattern edge model;

an external imaging device to capture the images at different focal distances;

a processor to, for each of the images, (i) scan the image, using the pattern edge model, to detect edge points of the image and (ii) compare the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

a calculator to, for each of the images, calculate a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image, wherein each of the standardized correlation values corresponds to one of the images;

a determinator to, for each of the images, determine an in-focus state of the image, based on the standardized correlation value for the image;

an image selector to select one of the images from the plurality of images, the determined in-focus state of the selected image matching a preselected in-focus state;
and

a measurer to process the selected image to measure the pattern.

22. (New) A pattern measuring apparatus comprising:

an edge model producing unit to produce a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

an external imaging device to capture images of a pattern to be measured with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

a storage device to store a plurality of images of the pattern and the pattern edge model produced by the edge producing unit;

a processor to, for each of the images, (i) scan the image, using the pattern edge model, to detect edge points of the image and (ii) compare the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

a calculator to, for each of the images, calculate a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image, wherein each of the standardized correlation values corresponds to one of the images;

a determinator to, for each of the images, determine an in-focus state of the image, based on the standardized correlation value for the image;

a measurer to, for each of the images, process the image to measure the pattern, if the determinator has determined that the in-focus state of the image matches a preselected state; and

a focal-position controller to, for each of the images, generate and output control signals to change the focal position of the optical system of the external imaging device, if the determinator has determined that the in-focus state of the image does not match the preselected in-focus state.

23. (New) A method of measuring a pattern comprising:

producing a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

capturing a plurality of images of a pattern to be measured with the use of an imaging device at different focal distances;

detecting edge points of each of the images by scanning the image using the pattern edge model;

comparing, for each of the images, the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

calculating, for each of the images, a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image, wherein each of the standardized correlation values corresponds to one of the images;

determining, for each of the images, an in-focus state of the image, based on the standardized correlation value for the image;

selecting one of the images from the plurality of images, the determined in-focus state of the selected image matching a preselected in-focus state; and

processing the selected image to measure the pattern.

24. (New) A method of measuring a pattern comprising:

producing a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of the image by scanning the image using the pattern edge model;

comparing the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

calculating a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image;

determining an in-focus state of the image, based on the standardized correlation value for the image;

processing the image to measure the pattern, if it has been determined that the in-focus state matches a preselected in-focus state; and

capturing a new image of the pattern at a different focal position, if it is determined that the in-focus state does not match the preselected in-focus state.

25. (New) A method of manufacturing a semiconductor device comprising a method of measuring a pattern including:

producing a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being

adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of the image by scanning the image using the pattern edge model;

comparing the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

calculating a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image;

determining an in-focus state of the image, based on the standardized correlation value for the image;

processing the image to measure the pattern, if it has been determined that the in-focus state matches a preselected in-focus state; and

capturing a new image of the pattern at a different focal position, if it is determined that the in-focus state does not match the preselected in-focus state.

26. (New) A method of manufacturing a semiconductor device comprising a method of measuring a pattern including:

producing a pattern edge model in a form of an array of cells, the array having a relative intensity value stored therein and a position of an edge point of the pattern edge model being assigned thereto;

capturing a plurality of images of a pattern with the use of an imaging device with an optical system at different focal distances, a focal position of the optical system being adjustable with respect to the pattern by an integer multiple of a predetermined step width from a predetermined initial value;

detecting edge points of the image by scanning the image using the pattern edge model;

comparing the pattern edge model to the intensity values of the image at the edge points to generate a plurality of correlation values, each of the correlation values indicating a correlation between the pattern edge model and the intensity value of the image at a respective edge point;

calculating a standardized correlation value based on the correlation values of the image, the standardized correlation value expressing a correlation between the pattern edge model and the detected edge points of the image;

determining an in-focus state of the image, based on the standardized correlation value for the image;

processing the image to measure the pattern, if it has been determined that the in-focus state matches a preselected in-focus state; and

capturing a new image of the pattern at a different focal position, if it is determined that the in-focus state does not match the preselected in-focus state.